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Processing and characterization of extended InP/GaInAs electron waveguides

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We present fabrication technology and characterization results of InP/GaInAs electron waveguides with lengths between 0.2 and 6 μm. The waveguides, all 100 nm wide, are produced by deep wet etching of high mobility 2DEG MOVPE-grown InP/$Ga_{0.25}In_{0.75}As$ structures. Typical mobility of the initial material is 450 000 cm^2/Vs and electron concentration is 3.5×10^{11} cm^{-2} [1]. The waveguide structures are defined by electron beam lithography at 35 kV and non-selective etchants HCl:CH_3COOH:H_2O_2 (HAP) [2] and a mixture of HBr:HNO_3:H_2O. A 250 nm-thick ZEP520 electron beam resist is used as an etch mask after post-development baking at 120°C to enhance its adhesion to the substrate [3]. These etchants give etch rate 10 and 3 nm/s for the HAP and HBr-based solutions, respectively and produce smooth InP surfaces suitable for immediate regrowth. After etching through the 2DEG layer, the structure is MOVPE-regrown at 600°C by nominally undoped 100 nm-thick InP layer to embed waveguides. To control the Fermi energy, we used a resist-insulated Au top gate made by a lift-off technique. The top view SEM images of 1 and 6 μm-long as-etched waveguides are shown in Figs. 1 and 2. Fig. 3 shows a typical example of the quantized conductance as a function of the top gate voltage in a regrown 100 nm-wide and 1 μm-long electron waveguide at 0.3 K. The effective channel width, calculated from the observed highest quantum number $n = 4$, is about 100 nm, which is equal to the lithographically defined channel width. It suggests no significant depletion of channel walls after epitaxial regrowth. We attribute it to the improvement of quality of the side walls by MOVPE regrowth. Temperature dependent measurements of the samples showthat the first and second conductance plateaus persist up to 7 K, which gives an energy separation between first and second subband at about 2.4 meV. This value is in agreement

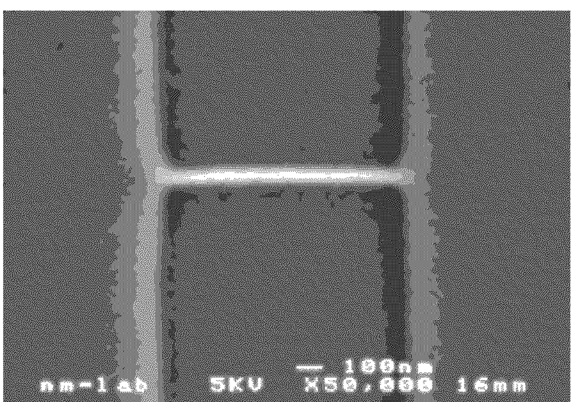

Fig. 1. SEM micrograph of 1 μm long, 100-nm wide electron waveguide produced in InP/$Ga_{0.25}In_{0.75}As$ 2DEG structure. The etching was performed in HCl:CH_3COOH:H_2O_2 solution at 4°C with ZEP 520 resist being an etch mask.

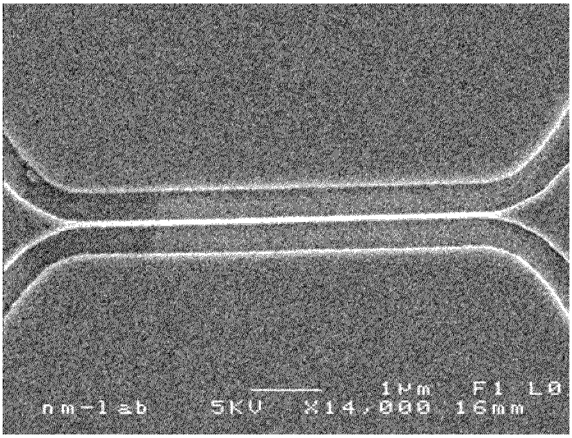

Fig. 2. SEM image of as-etched 6 μm long, 100-nm wide electron waveguide with side gates. Orientation of the waveguide is [110].

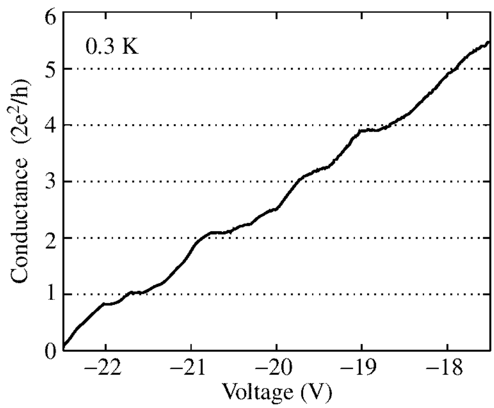

Fig. 3. Conductance, at 0.3 K, as a function of top gate voltage in the 100 nm-wide and 1 μm-long InP/$Ga_{0.25}In_{0.75}As$ waveguide, regrown with undoped InP.

with the calculation for a 100 nm wide channel by using a hard wall square-well potential.

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